Cooperative Human-Robotic Roles in EVA Work Sites

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Historical Perspective

- **Humans and robots as competing systems**
  - **Competition for limited funding resources**
  - **Excesses on both sides**
    - **Robotics supporters denounce EVA as inherently unsafe**
    - **Human supporters denounce robots as inherently unsafe**
- **Humans or robots as default systems**
  - **Use EVA when humans are present**
  - **Use robotics when humans are not present**

Current EVA/Robotic Interaction
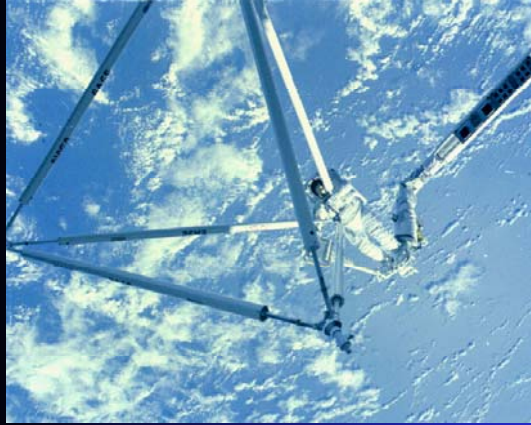
EVA view:

Robot as a mobile foot restraint

Robotics view:

Human as dexterous end effector

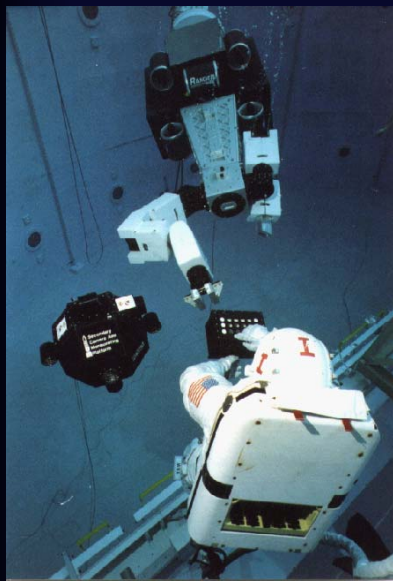**Composite view:**

Capabilities beyond either system working alone

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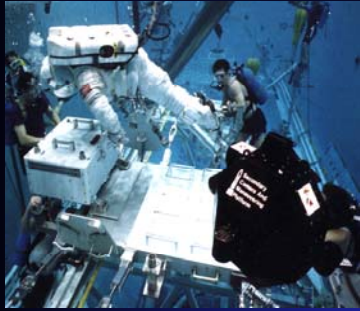# Future Cooperative Work Sites

- Robots as observers /Humans perform tasks

- Robots as assistants /Humans perform primary tasks

- Robots as associates /Humans perform selected tasks

- Robots as surrogates /Humans perform limited or no direct tasks

- Robots as specialists /Humans as specialists

- Robots and humans in symbiosis

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Robots as EVA Observers

- Free-flying camera platforms for flexible external view points
- Supplemental Camera and Mobility Platform (SCAMP) developed by UMd in 1991 as prototype for testing free-flying camera platform in EVA and robotic operations
- Extensively tested as neutral buoyancy monitoring system, observation platform for HST servicing, monitoring of EVA training at JSC WETF
- AERCam/SPRINT (flown on STS-87, November 1997)


Robots as EVA Assistants
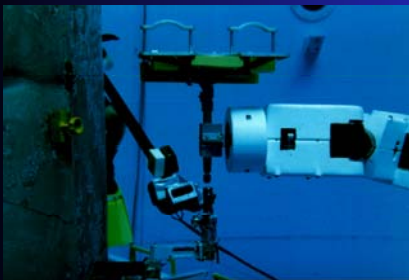
- Robots to carry hardware, fetch tools, prepare work sites, and otherwise offload EVA crew
- Beam Assembly Teleoperator (BAT) developed by SSL in 1984 to perform EASE EVA structural assembly task
- Used to assist EVA crew in HST servicing operations (work site preparation, opening and closing access panels, bringing/removing/stowing ORUs)
- Saves limited EVA time for demanding or critical tasks

Robots as EVA Associates
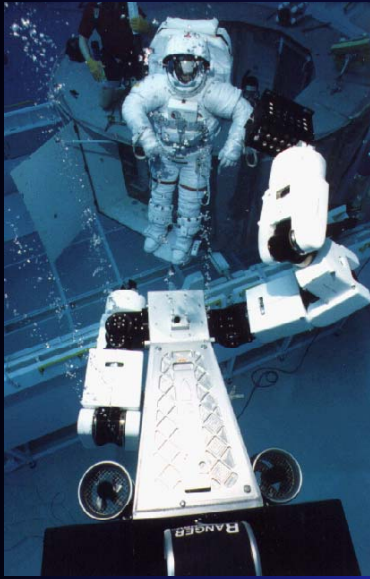
- **Robots performing tasks at comparable effectiveness (dexterity and speed) to EVA crew, and directly interacting**
- **Ranger Neutral Buoyancy Vehicle (NBV) developed by SSL in 1995 as EVA-capable robot**
- **Tested in cooperative EVA/robotic servicing of Hubble Space Telescope**
- **Planned for space flight validation in 2003**
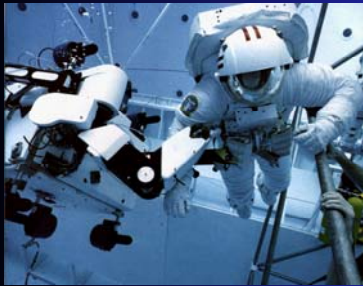
Robots as EVA Surrogates
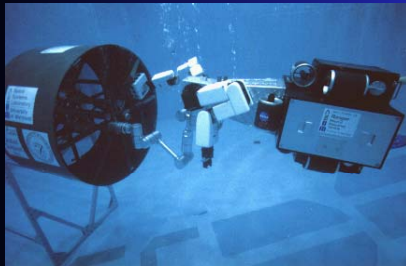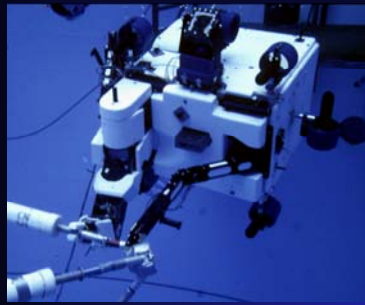
- **Robots capable of performing the same tasks, using the same interfaces, as EVA crew**
- **Necessary for locations inaccessible to humans (geostationary orbit) or for missions precursor to human exploration**
- **Dexterity, strength, and speed must rival or exceed human**
- **Robust and reliable systems required**
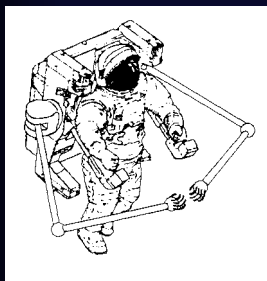
Robots as Specialists

- **Robotic systems specialized for specific tasks**
- **Currently demonstrated by Shuttle RMS with foot restraints**
- **Interesting possibilities such as astronaut support vehicle, robotic lifeguard, etc.**

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# Robot/Human Symbiosis

- **Use of robotics technologies to directly support/augment/enhance human capabilities**
- **Power Glove (developed by UMd and ILC Dover) reduces hand fatigue by robotic system to supplement hand force**
- **Addition of robotic manipulation capability to suit systems**
- **Hard suit/"man-in-a-can" approach for human presences in hazardous environments (e.g., geostationary orbit)**
- **Ultimate paradigm of powered suit for extended EVA operations**

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EVA/Robot Cooperation on Planets
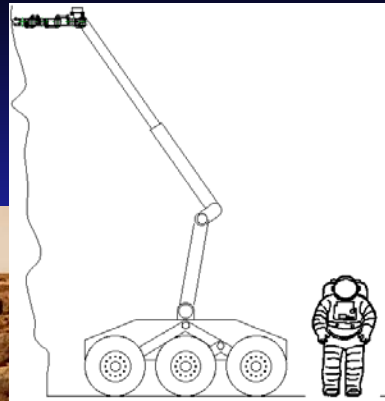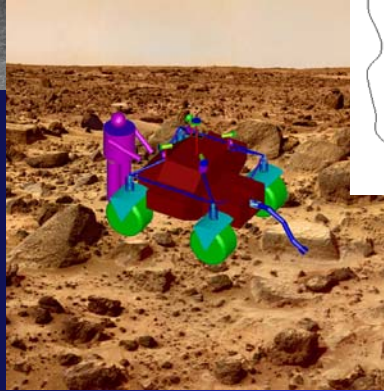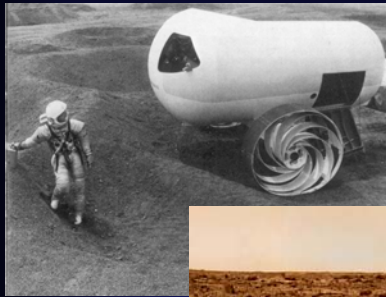
Robots for Planetary Exploration

- **Robotics are critical for extending and expanding human capabilities in a gravitational field**

- **Planetary surface concepts envision layers of robots in support of human explorers, including**
  - **Multiple interacting/cooperating microrovers for survey and exploration**
  - **Human assistant robots for geology and search for nonterrestrial life traces**
  - **Highly dexterous telepresence systems for hazardous exploration activities (e.g., geology on cliff faces)**
  - **Specialized robotic systems for tasks such as drilling and coring, surveying, etc.**
  - **Major interactive systems such as pressurized rovers and aerial surveying RPVs**

- **Robotics for precursor missions should be designed to be compatible with EVA systems and operations**

Robotic-Assisted HST Servicing
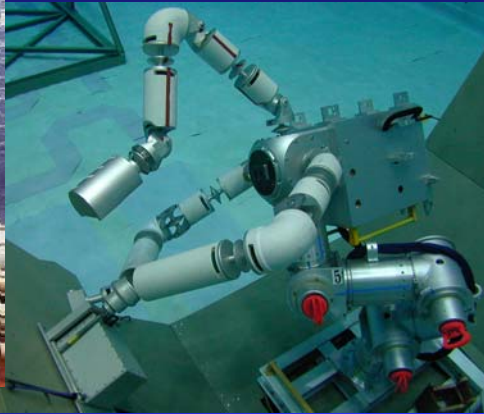
Detailed Analysis: HST Servicing

- **Detailed timeline data taken from HST servicing missions to date (SM1 data presented here)**
- **Application of Ranger TSX as a supporting robotic capability to EVA operations**
- **Identify fraction of each task which is best performed by robot, split between time frame**
  - **Prior to EVA**
  - **During EVA**
  - **After EVA**
- **Apply appropriate multiplier for robotic productivity (robot performance time = 3 X EVA for this example)**

SM1 Timeline with Robotic Assistance

Hubble Space Telescope First Servicing Mis

Legend: Ranger (pre-EVA) | EV1 - with Ranger | Ranger (during EVA) | EV2 - with Ranger | Ranger (post-EVA)

X-axis: EVA Day (1, 2, 3, 4, 5)

Y-axis: 0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00
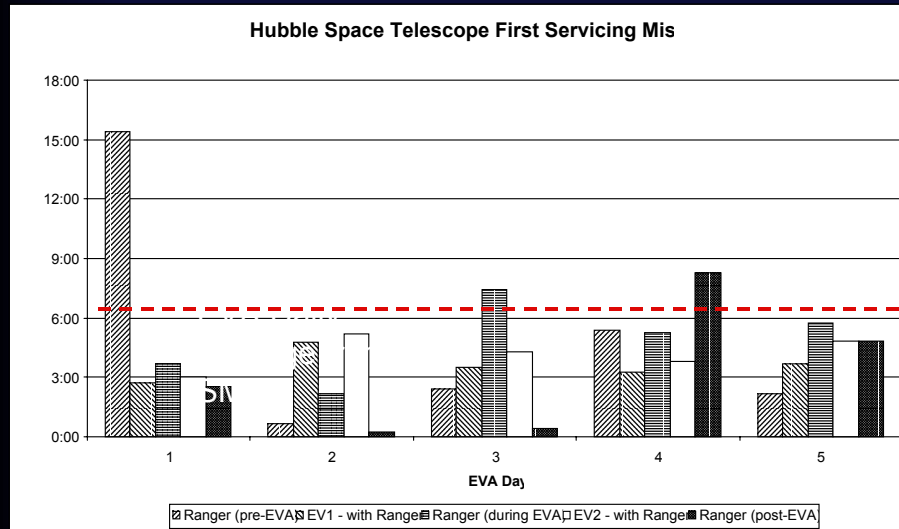
Preliminary Results of SM1 Robotics

- **EVA timelines reduced by 40%**
  - **EV1 reduced by 42%**
  - **EV2 reduced by 34%**
  - **Total savings in EVA time 23:34 (reduced from 62:37 to 39:02)**
- **Study to date has been restricted to SM1 timelines and procedures**
- **Could further benefit from timelines optimized for EVA/robotic interactions**
- **Even limited analysis demonstrates enormous benefits to EVA/robotic cooperation**
  - **Reduce from 5 to 3 EVAs; cut EVA crew from 4 to 2**
  - **Increase servicing operations by 65% per mission**
  - **Perform servicing robotically during crew 0G acclimatization**

Future Human/ Robotic Roles

- **All current experience indicates that teams of humans and robots, working cooperatively in an integrated work site, are the most capable and productive method for space operations**

- **Don McMonagle (former NASA EVA Program Lead):**

  "In the future, EVA and robotics will be synergistic, if not synonymous."

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